# *Characteristics and Various Applications of Vanadium Redox-Flow Battery (VRB)*

Background of the Development
Principle
Characteristics
Various Applications

*SUMITOMO ELECTRIC INDUSTRIES, Ltd.*

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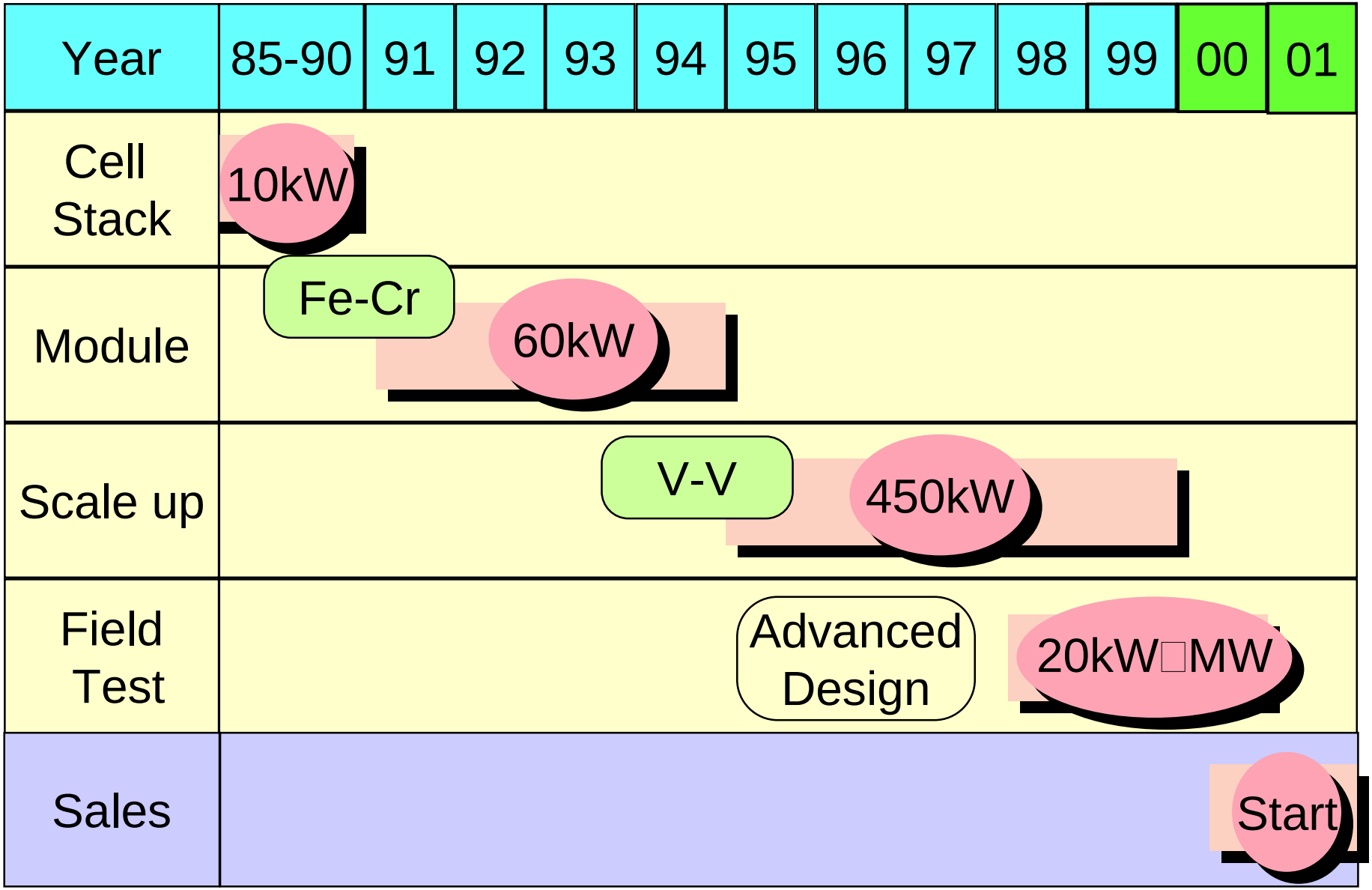
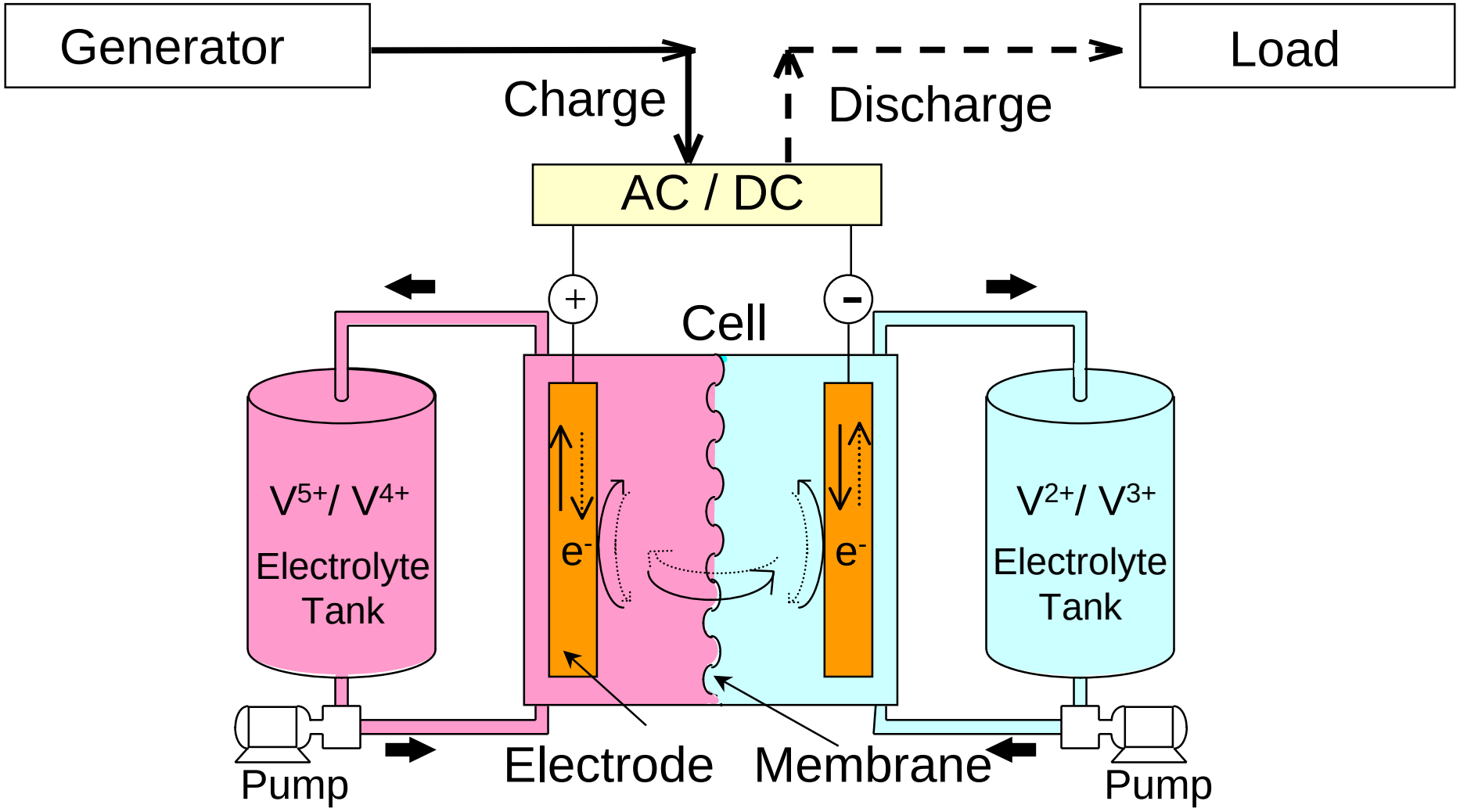
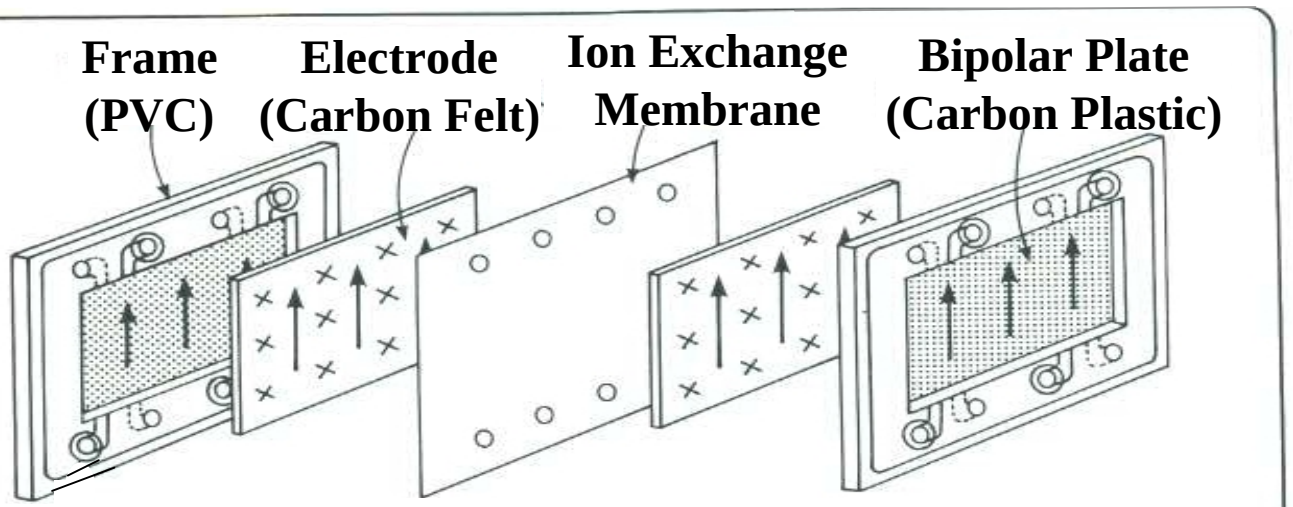
# Vanadium Redox Flow Battery Development Program



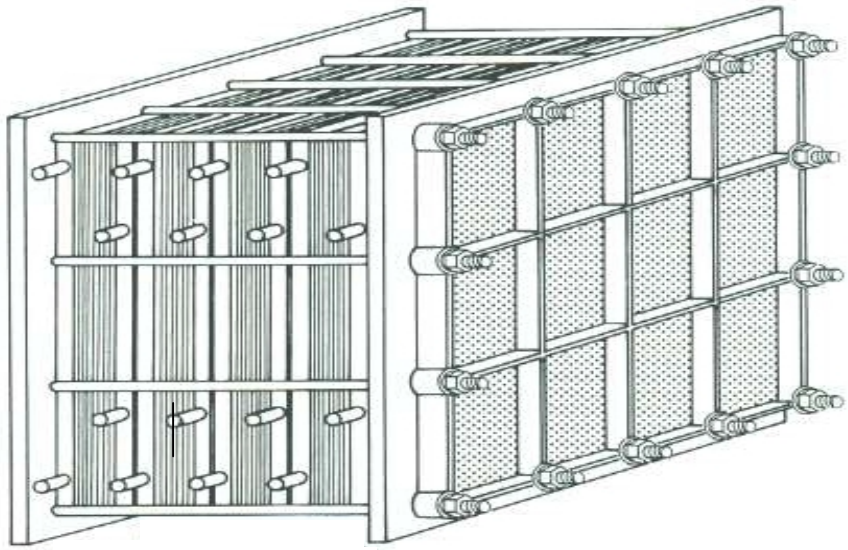
# Principle of Vanadium Redox Flow Battery



# Construction of Cell Stack




Components of a cell



# Characteristic Advantage of VRB

1. High-rate Overload Capacity
2. Quick Response

→ UPS, LFC, Stabilization of Wind Turbine Output

3. Long Cycle Lifetime in Deep Charge/Discharge

→ Load Leveling

4. Easy Increase of Capacity

→ Large Storage Capacity System

5. Normal Temperature Operation
6. Environmentally Friendly

→ Safe and Green

# Various Applications of VRB

1. Load Leveling
2. UPS
3. Storage and Stabilization of Photovoltaic and Wind-Generated Electricity
4. Power Quality Control

   Load Frequency Control (LFC)
   Spinning Reserve
   Stabilization of Flicker

# VRB Projects in Japan

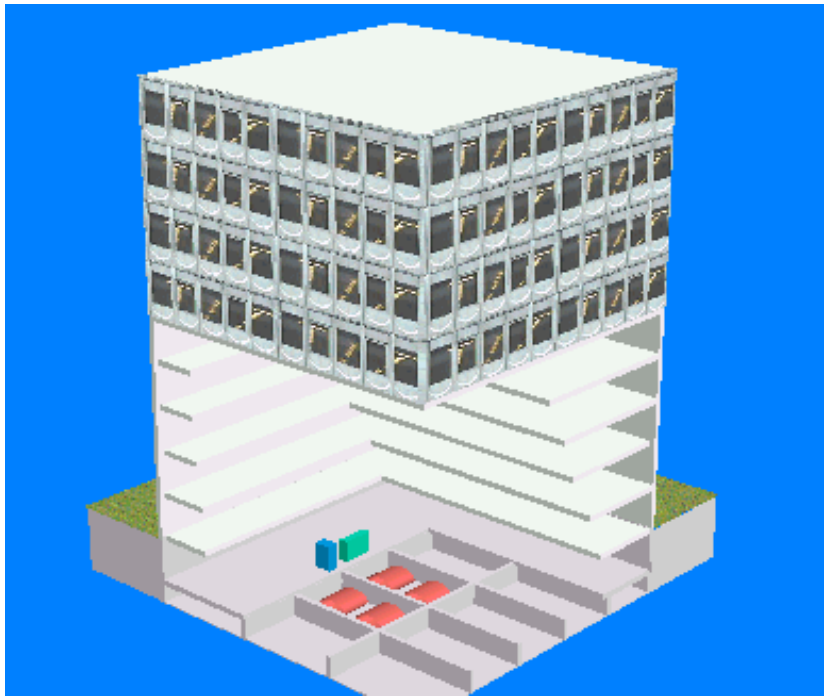
## Awarded Projects

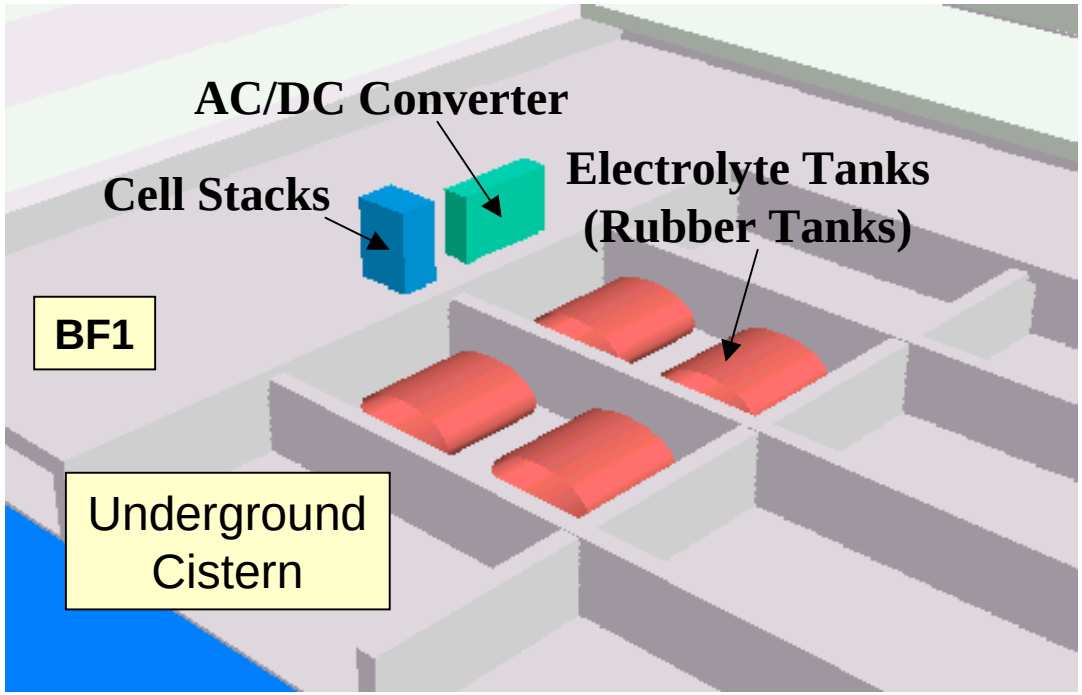
| Place | Applications | Specifications | Start of operation |
|---|---|---|---|
| Office building | Load leveling (Demonstration) | 100kW x 8h | 2000/02 |
| Semi-conductor factory | 1) Voltage sag protection<br>2) Load leveling | 1) 3000kW x 1.5sec.<br>2) 1500kW x 1h | 2001/04 |
| Wind power station | Stabilization of wind turbine output (Field test) | 170kW x 6h | 2001/04 |
| Golf course | Load leveling (Photovoltaic hybrid system) | 30kW x 8h | 2001/04 |

# Application to Office Building

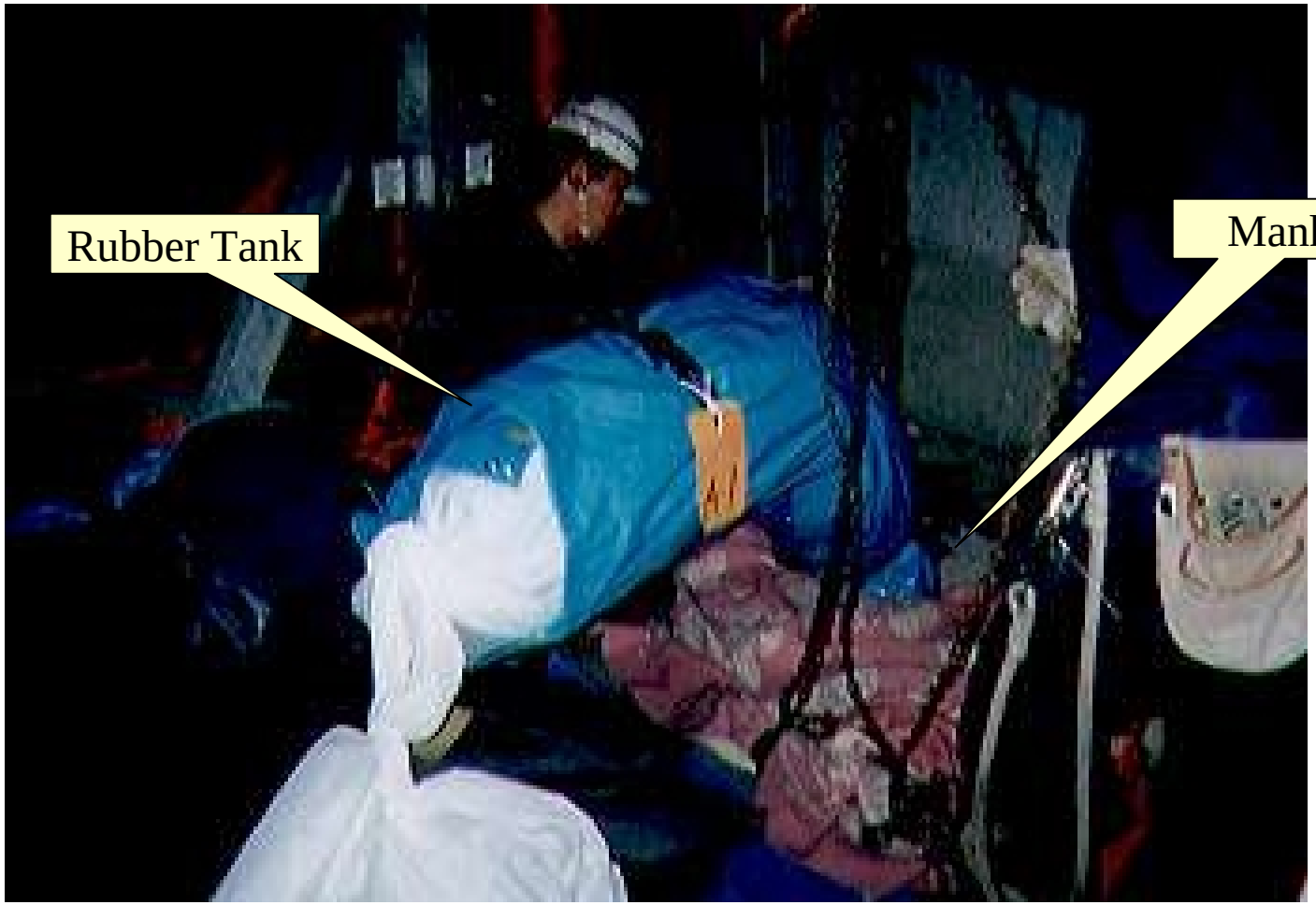
| | |
|---|---|
| **Capacity** | **100kW-8h** |
| **Place** | **SEM, Osaka** |
| **Start of operation** | **February 2000** |

| | |
|---|---|
| **Battery module** | **25kW cell stack x 4** |
| **Tanks** | **350 ft$^3$ x 4** |





# Carrying Rubber Tank to Manhole

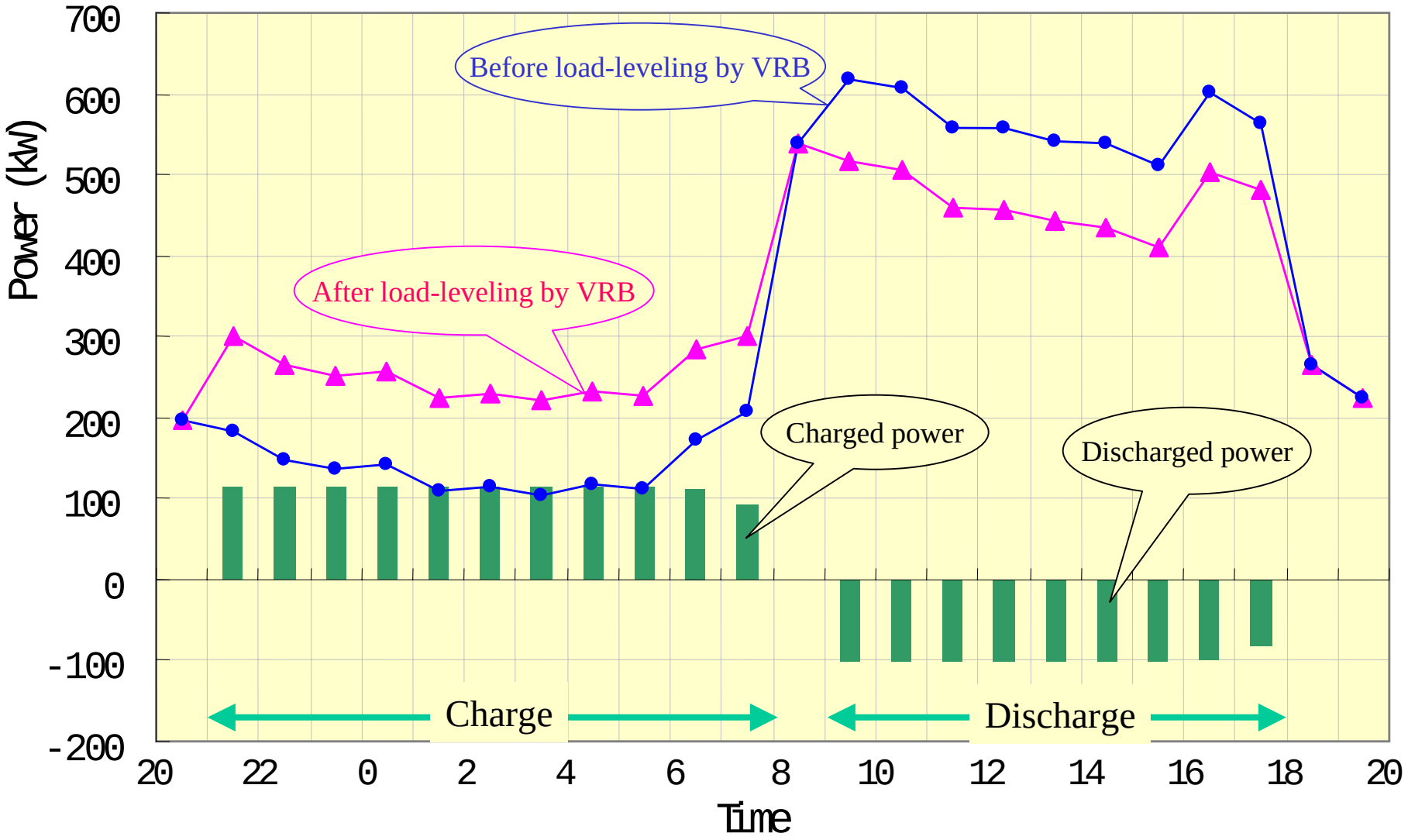



**Manhole - 60cm dia. - was an only way into tank space.**

**Rubber tank was bound to a roll of 40cm dia.**

**No reconstruction of building was done for installation of rubber tank.**

# Load-Leveling Operation of 100kW VRB

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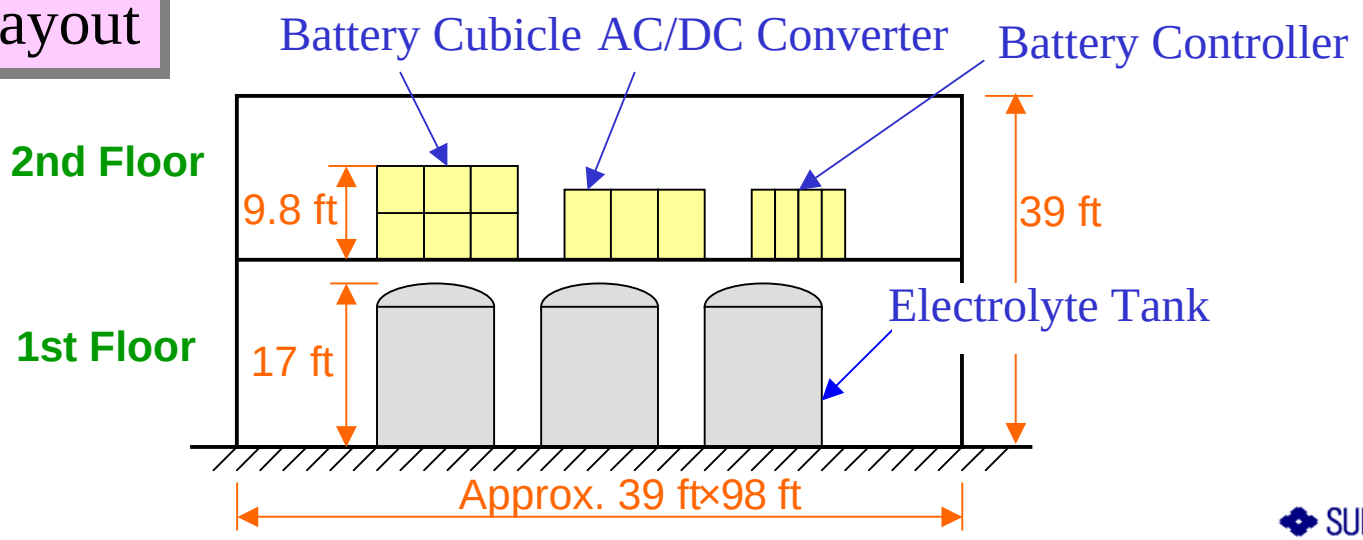
# Application to Semi-Conductor Factory

## Specifications

Operation - First of April 2001

| Function | Purpose | Output | Operation |
|---|---|---|---|
| (1) Voltage Sag Protection | Protection of Important Load | 3MW x 1.5 sec | At the Occurrence of Voltage Sag 5 - 20 times /year |
| (2) Load leveling | Reduction of Electricity Charge | 1.5MW x 1hour | Everyday |

## System Layout

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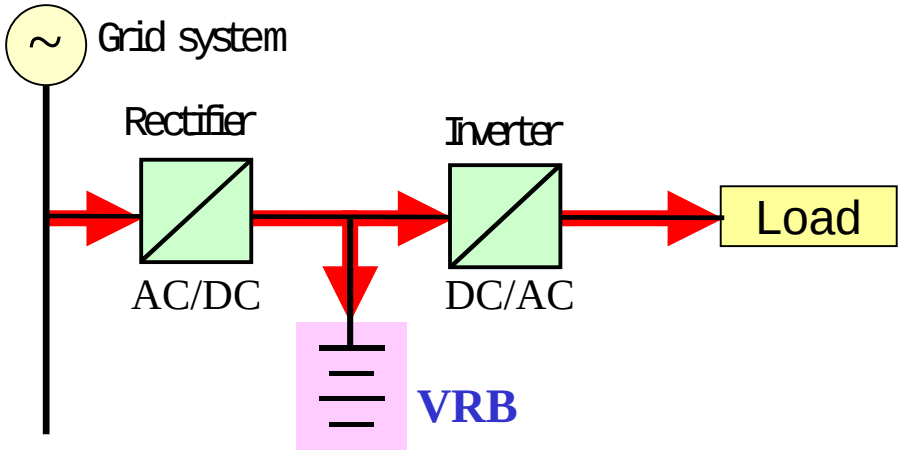
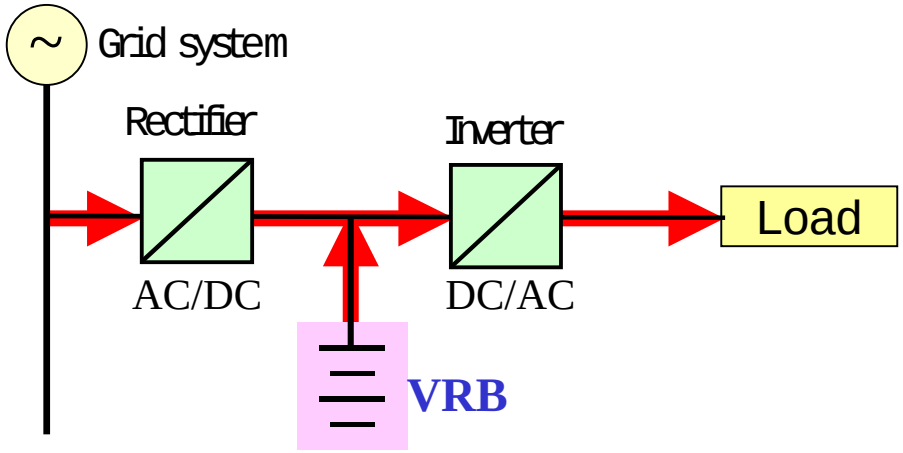
# Operation Sequence

## Load leveling (Normal operation)

### Charge

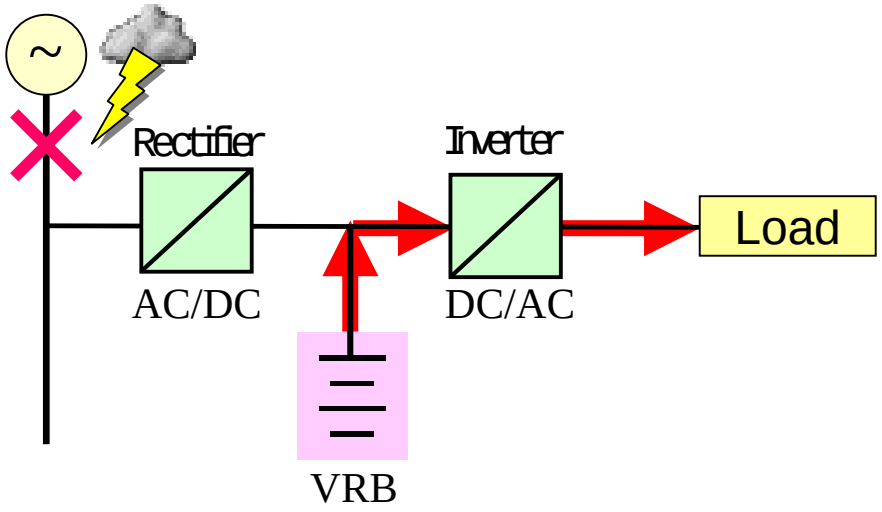



### Discharge

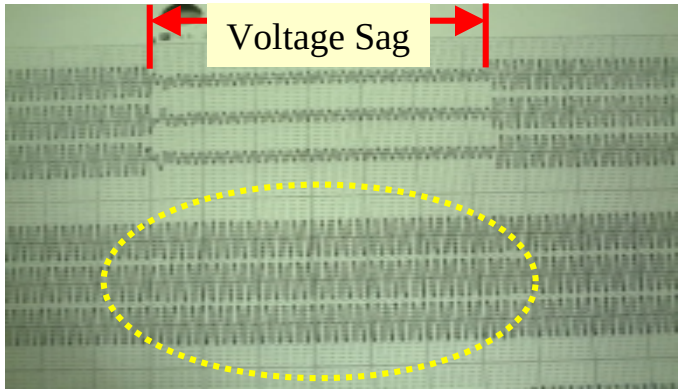



## UPS function

### Voltage sag protection




**Test result for voltage sag (0.5sec)**

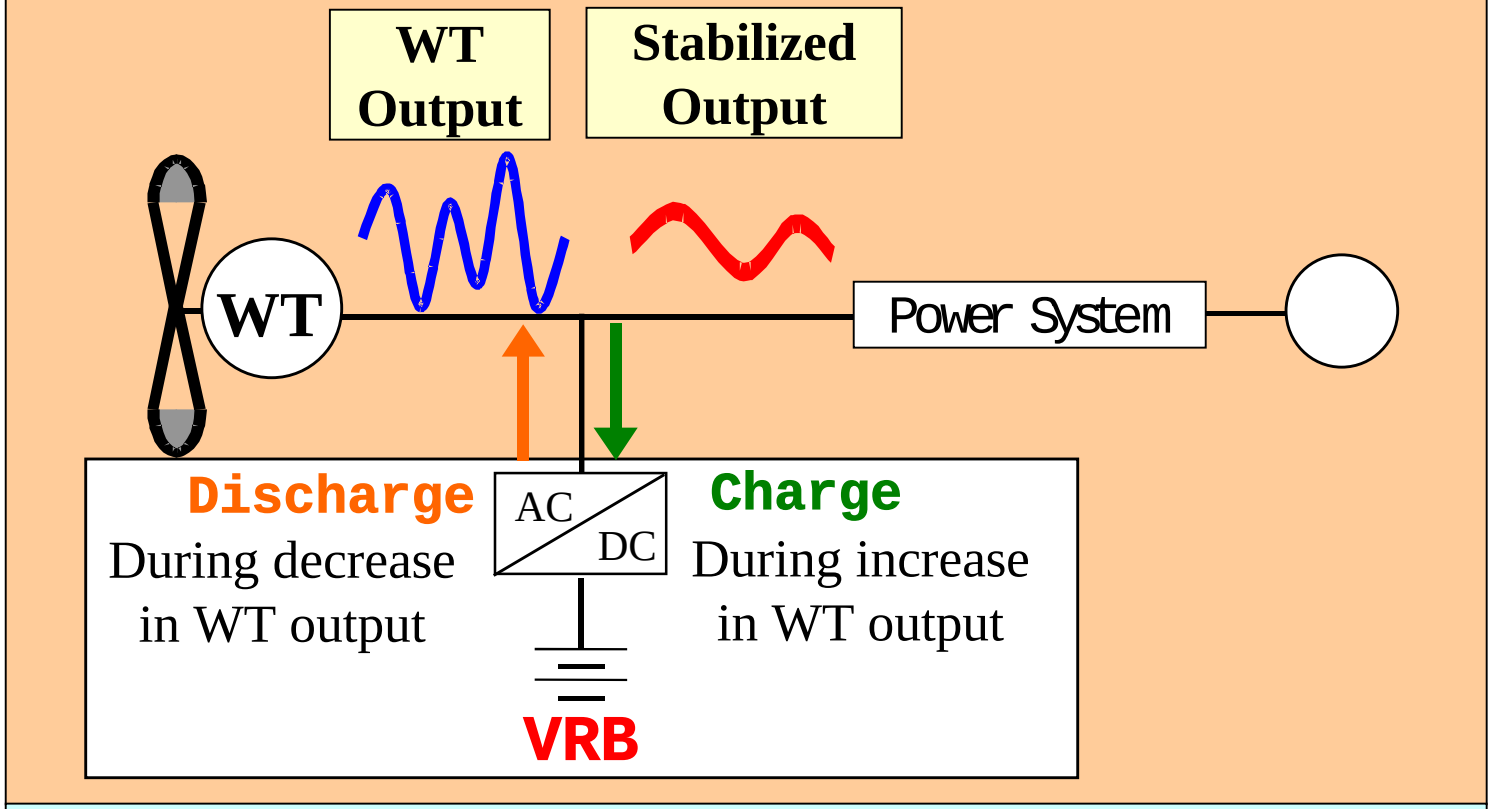


# Application to Wind Power Station (NEDO Project)

**Purpose - Field test for stabilizing of output**

**Spec. - 170kW×6h**

Commission: NEDO → IAE (The Institute of Applied Energy) → Order: SEI




01/4/F ~ 9/E Field test ~ 02/2/E Data analysis

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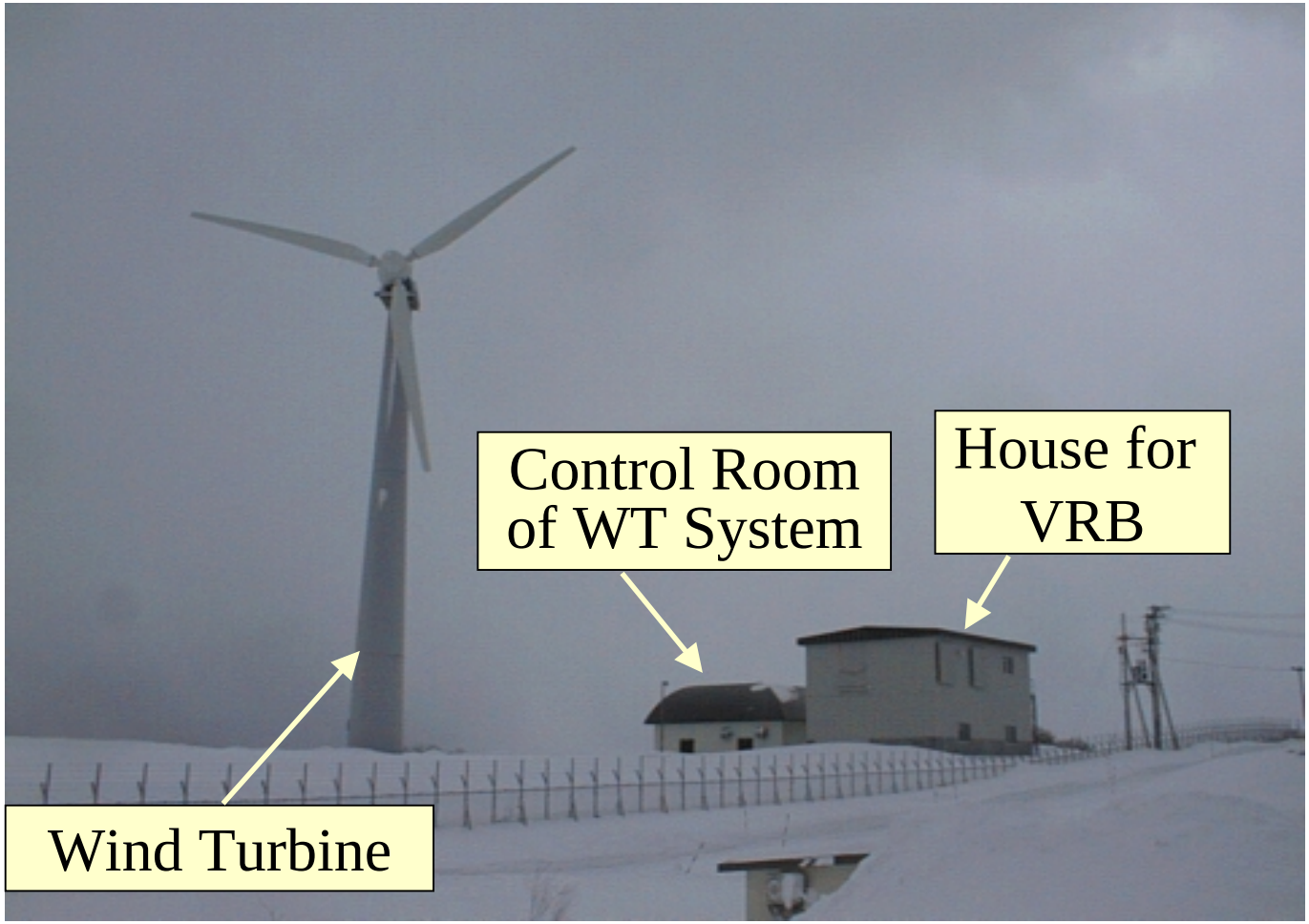
# Appearance of VRB and Wind Turbine

Place : Tomari Wind Hills of Hokkaido Electric Power Co.,Inc.
Wind Turbine : 250 kW
VRB : 170 kW-6h



# VRB Equipment

## Battery Cubicle

## AC/DC Converter

## Electrolyte Tank

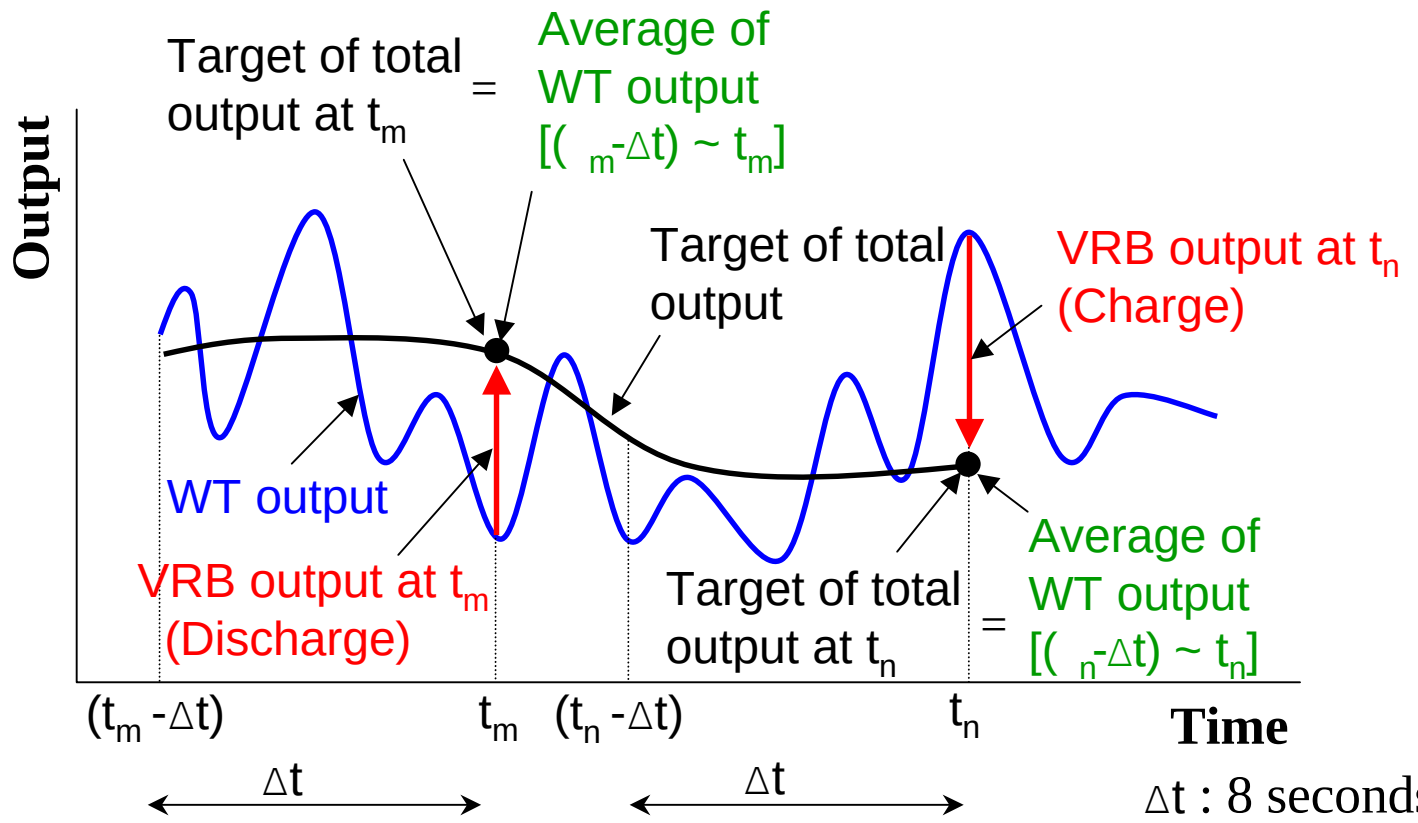
# Field Test for Stabilization of WT Output

<Operation Outline>

Target of total output (t) = Average of WT output [(t-Δt) ~ t]

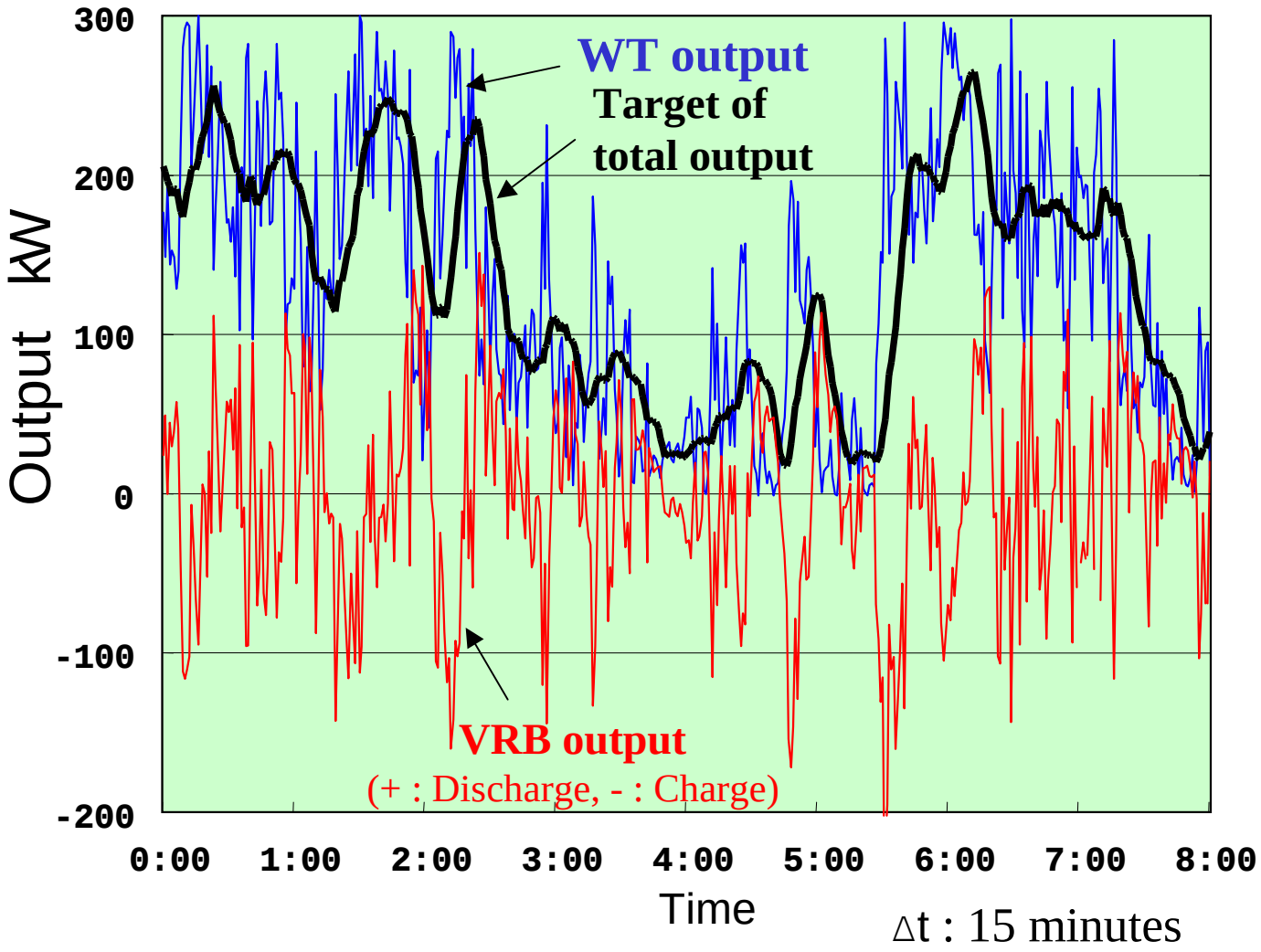
VRB output (t) = Target of total output (t) - WT output (t)

(+ : Discharge, - : Charge)




Δt : 8 seconds ~ 8hours

# Example of Simulation Results for Stabilization of WT Output

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# Field Test for Effective Utilization of WT Output

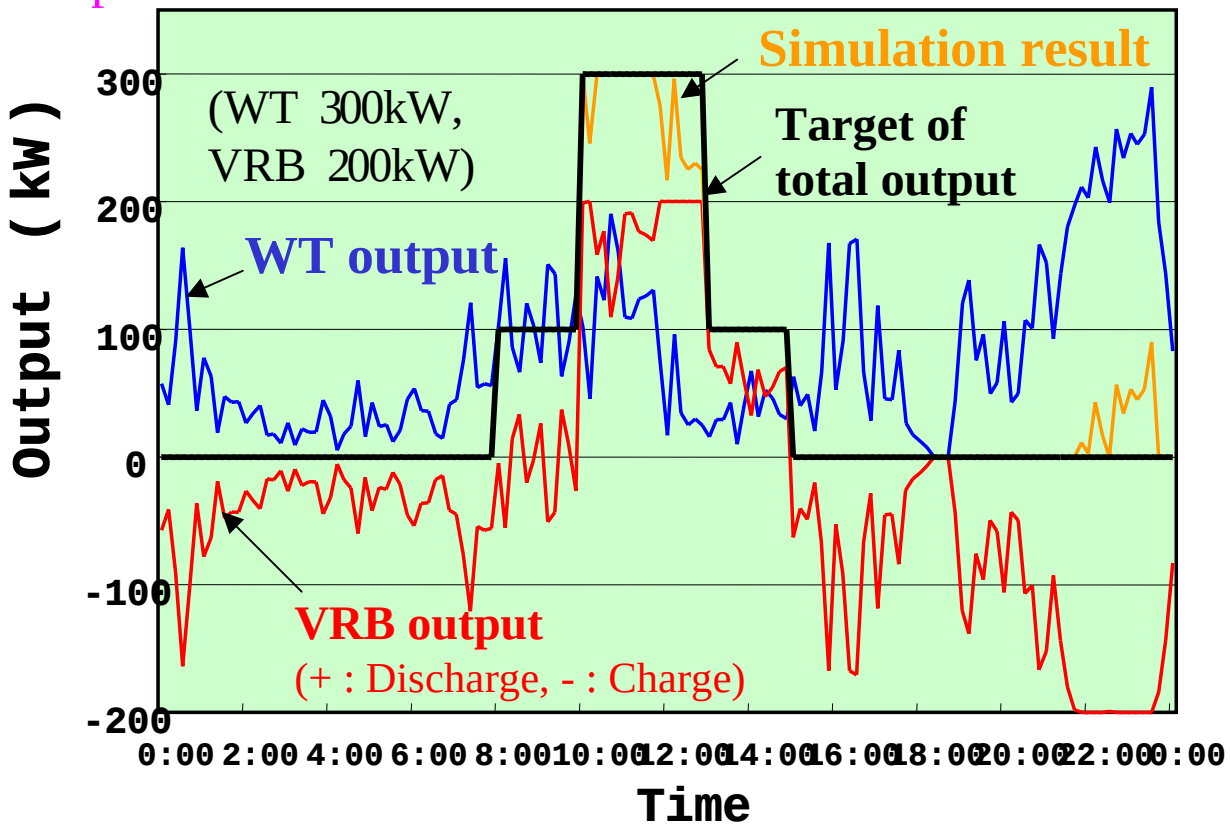
<Method>

VRB is charged by WT output when demand is low, and
VRB is discharged when demand is high.

<Operation>

Target of total output is set up considering the demand in advance.
VRB output = Target of total output - WT output

<Example of simulation results>

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# Application to Golf Course
## (Hybrid System of VRB and Photovoltaic Generation System)

### <Specifications>

Load leveling of DC load in golf course

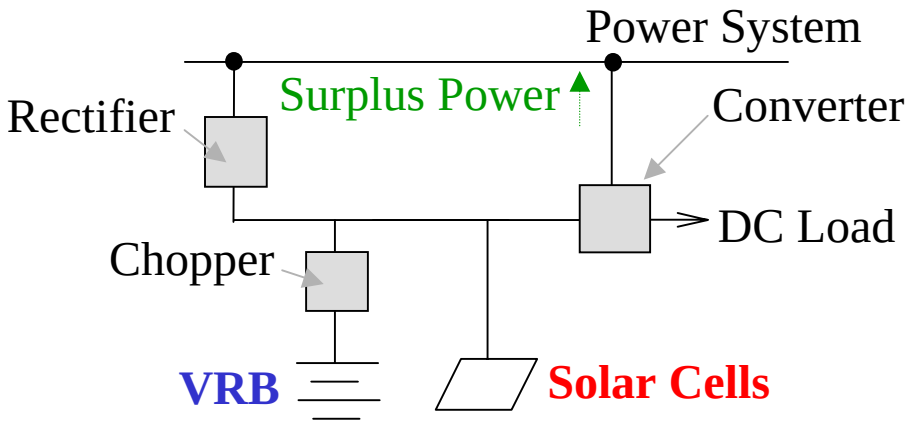
( Light in club house)

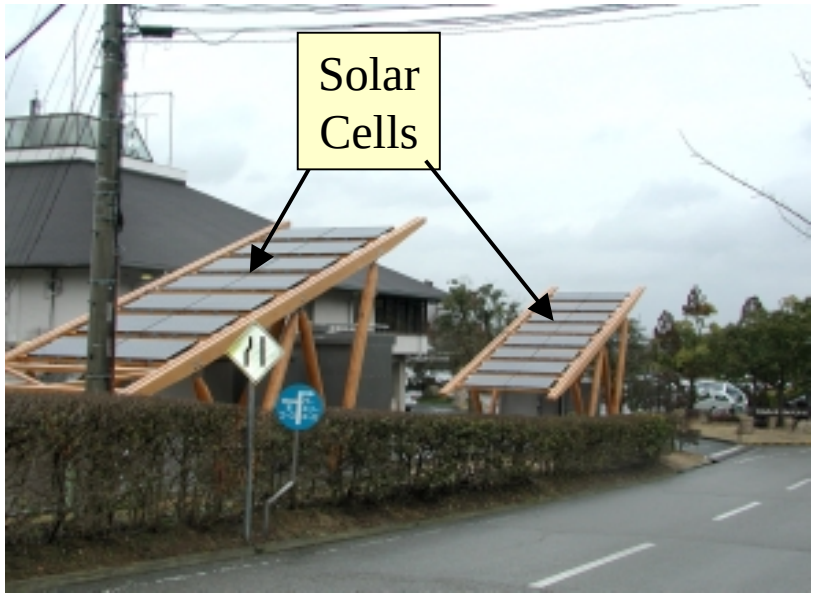
30kW×8h

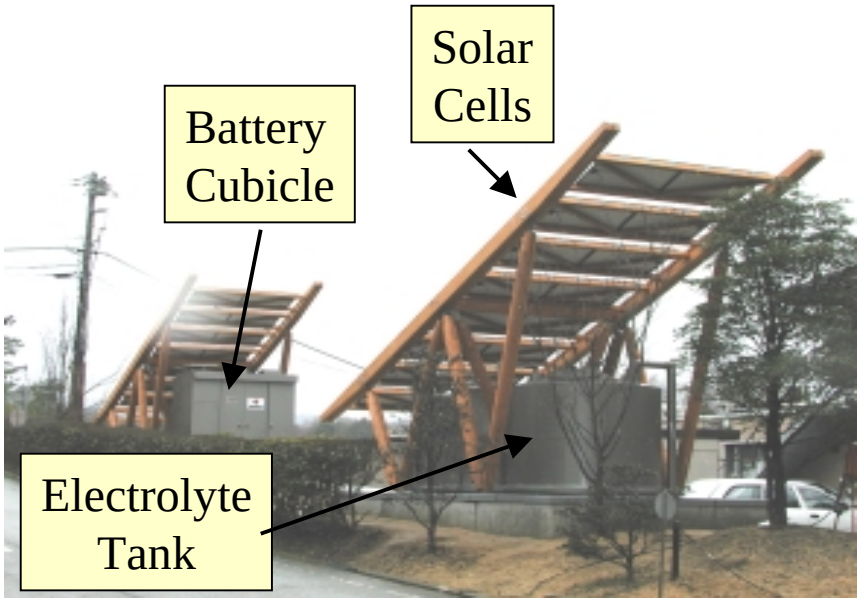
### <Schedule>

Operation → First of April 2001

### <System Diagram>

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# Power Quality Control

## Purpose

1. Load Frequency Control (LFC)
2. Spinning Reserve
3. Stabilization of Flicker

Presentation in IEEE PES Winter Meeting (‘01/1/28~’01/2/1)
by Kansai Electric Power Co., Inc.

Basic data collected by the experiment of 1kW (1kWh) VRB.
Simulation results of VRB utilization for power quality.